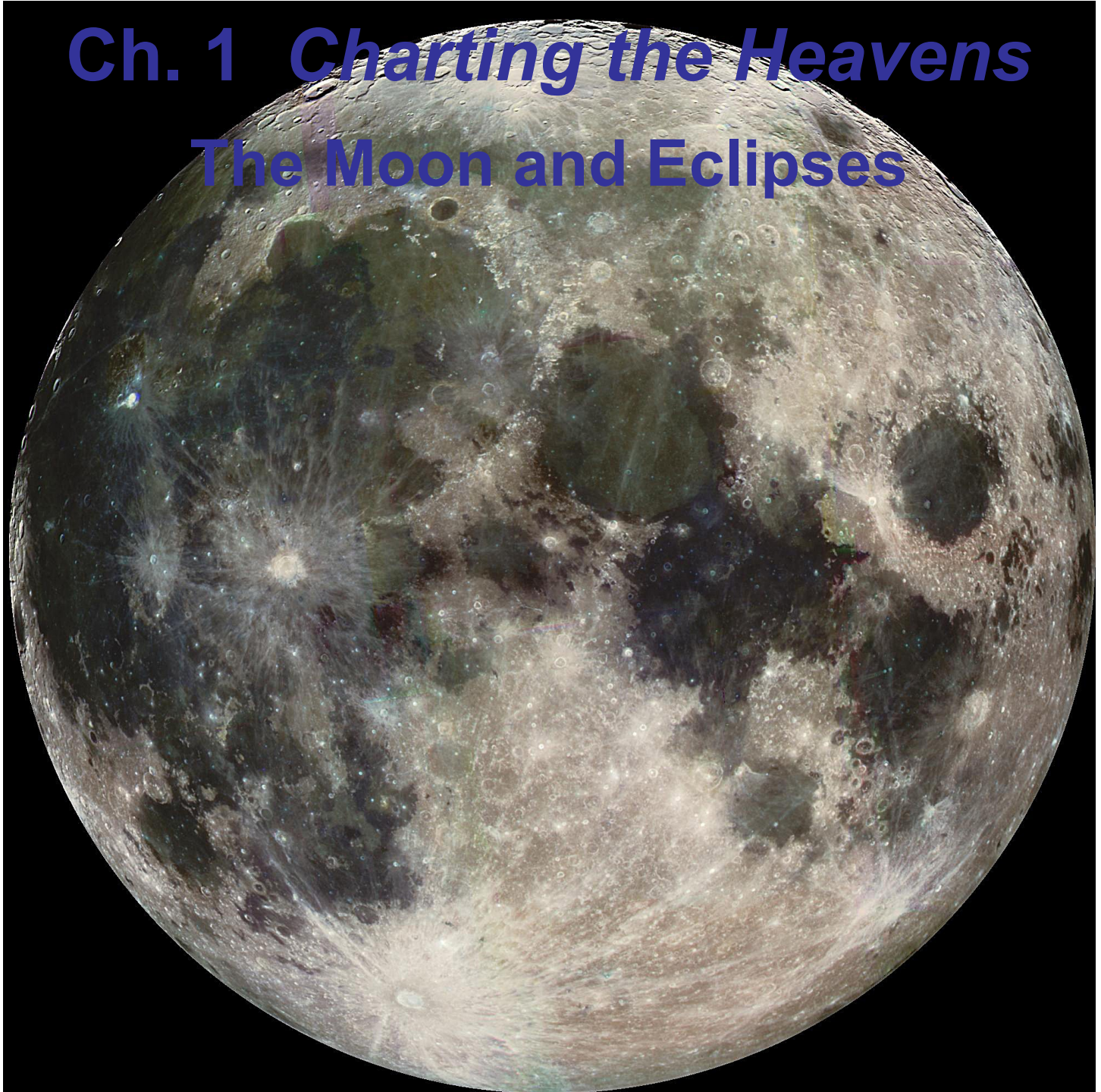
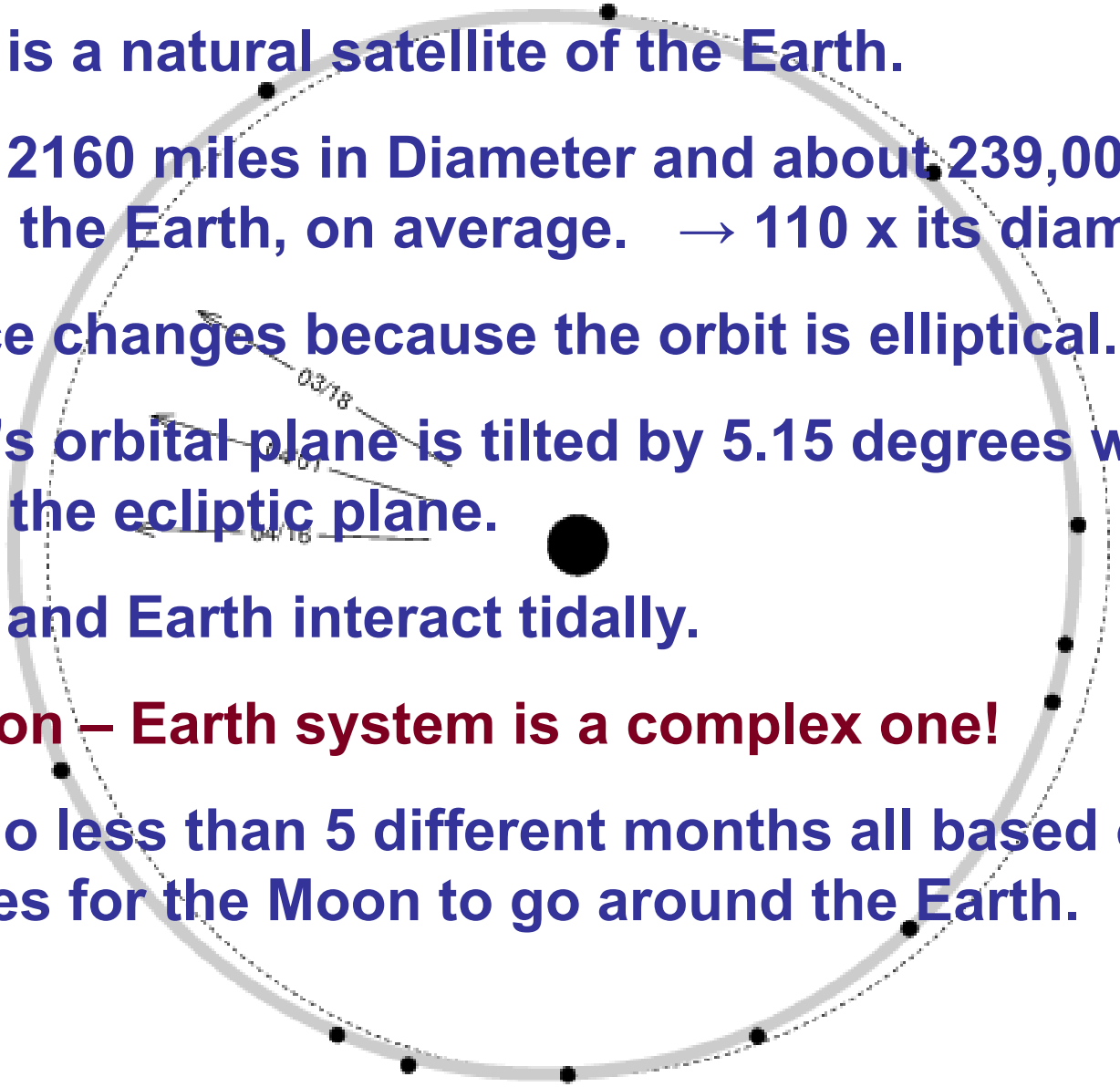
Ch. 1 *Charting the Heavens*

The Moon and Eclipses



1.5 Motion of the Moon



The Moon is a natural satellite of the Earth.

It is about 2160 miles in Diameter and about 239,000 miles away from the Earth, on average. → 110 x its diam away

Its distance changes because the orbit is elliptical. (e=.055)

The Moon's orbital plane is tilted by 5.15 degrees with respect to the ecliptic plane.

The Moon and Earth interact tidally.

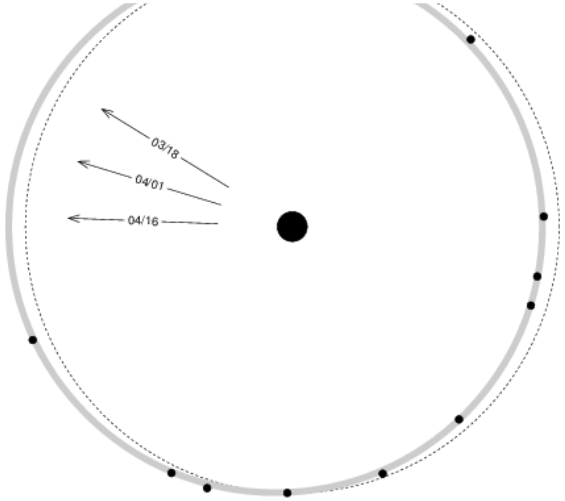
→ The Moon – Earth system is a complex one!

We have no less than 5 different months all based on the time it takes for the Moon to go around the Earth.

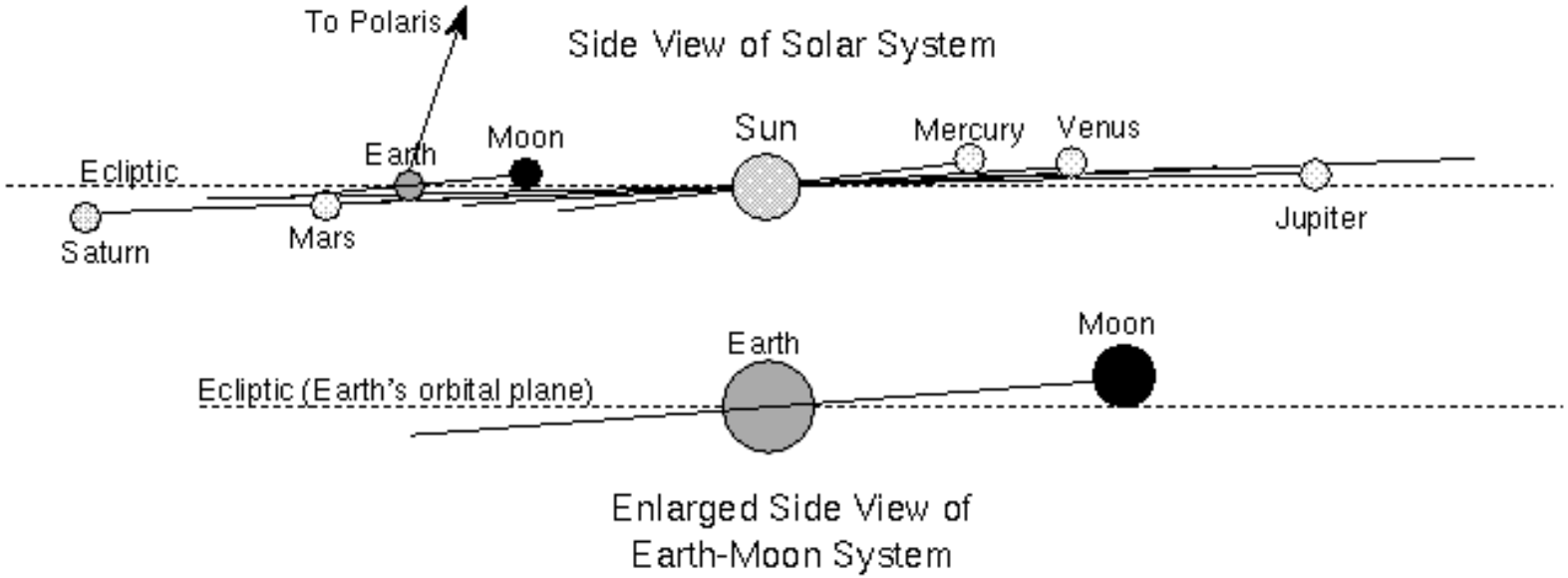
© 2011 Pearson Education, Inc.

Tilt of the Moon's orbit

Top View:



Side View:

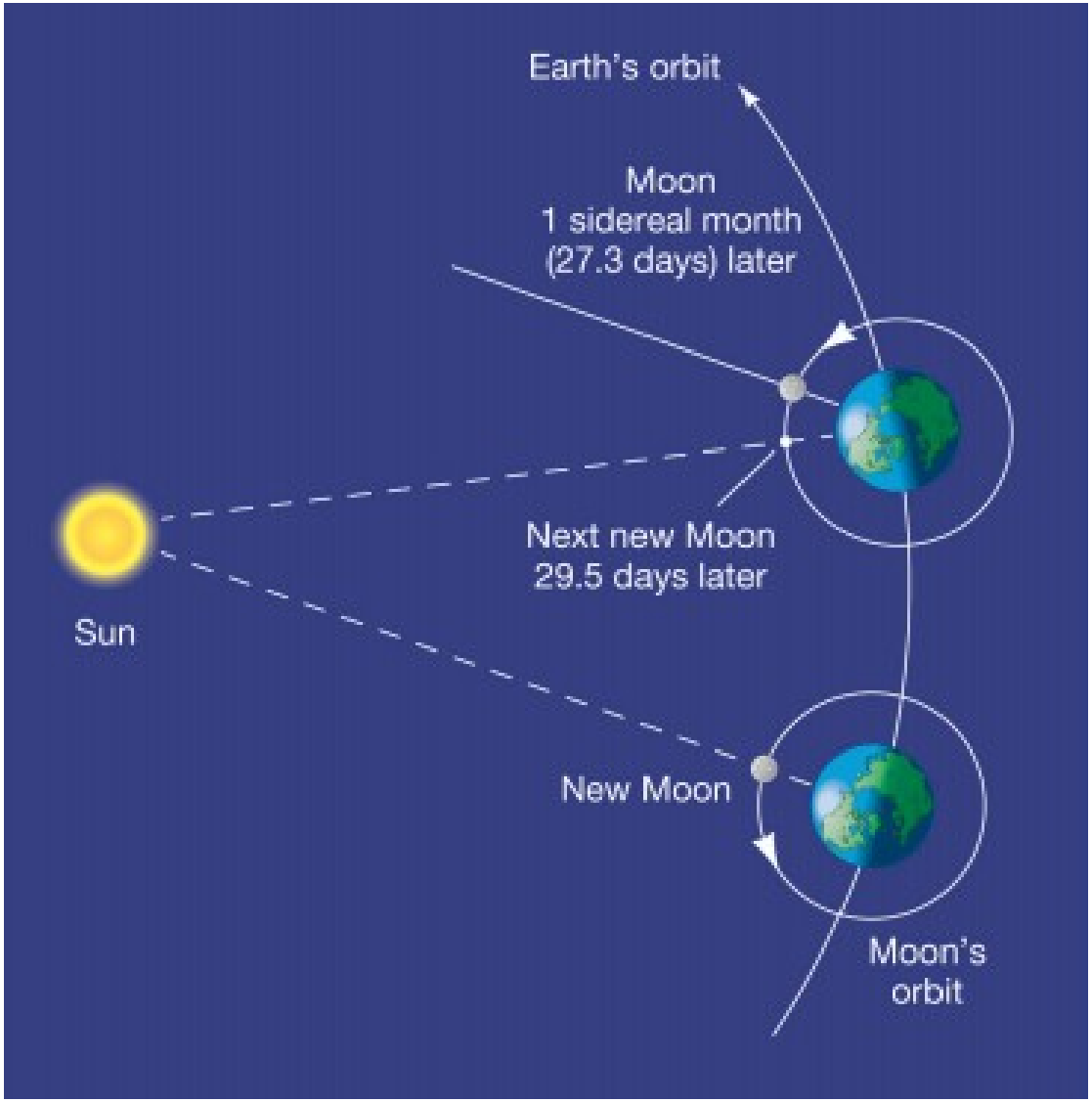


© 2011 Pearson Education, Inc.

1.5 Motion of the Moon

1) **Sidereal Month:** time to orbit relative to stars = **27.3** days.

2) **Synodic Month:** time to orbit relative to Sun = **29.5** days. Same as the "phase month".

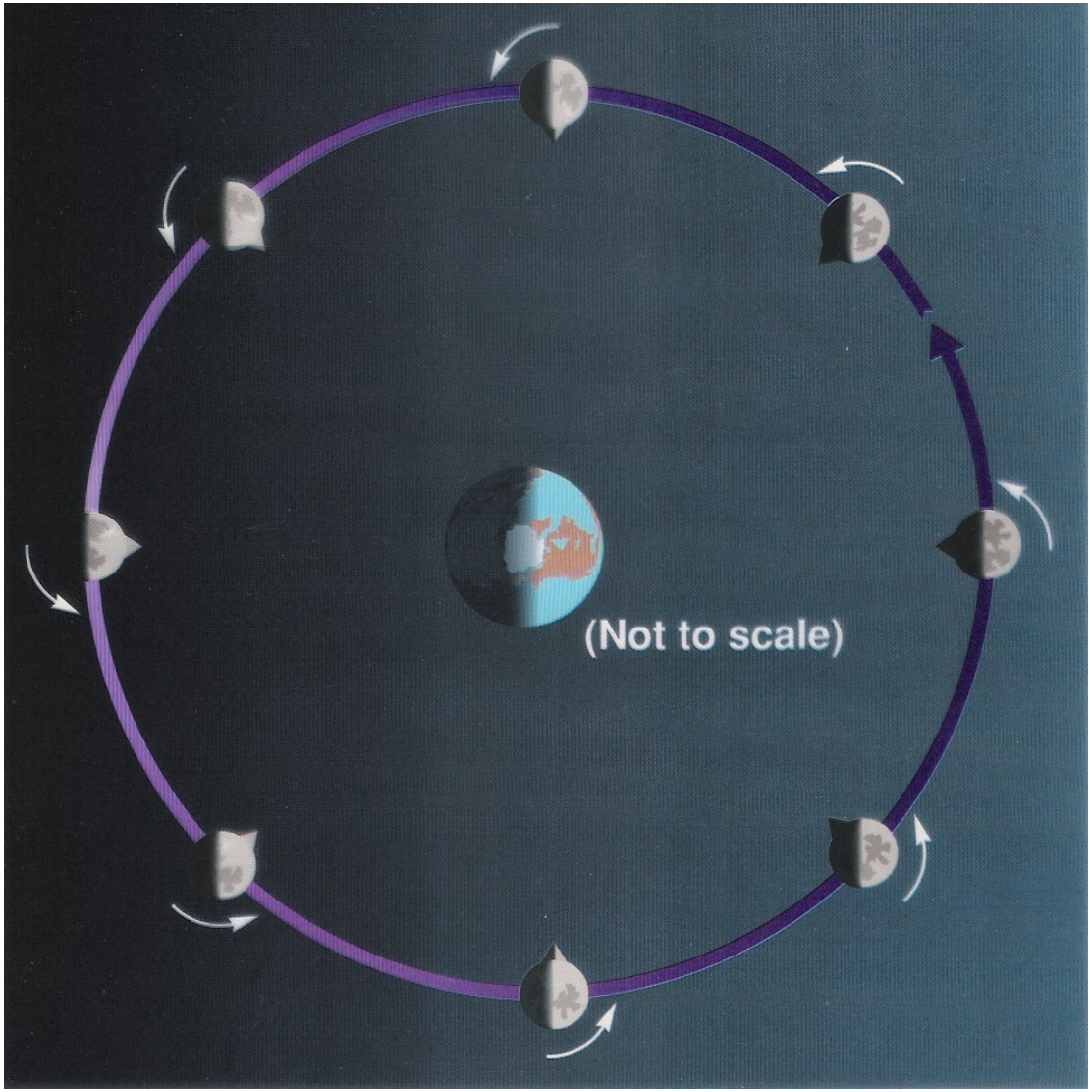


Why is the synodic month longer?

How fast does Moon move relative to stars?

Q: Does the Moon rotate? (Relative to stars? Earth?)

Q: Is there a "dark side" of the Moon, or a "far side"?



See Moon globe, and YouTube videos about *libration*.

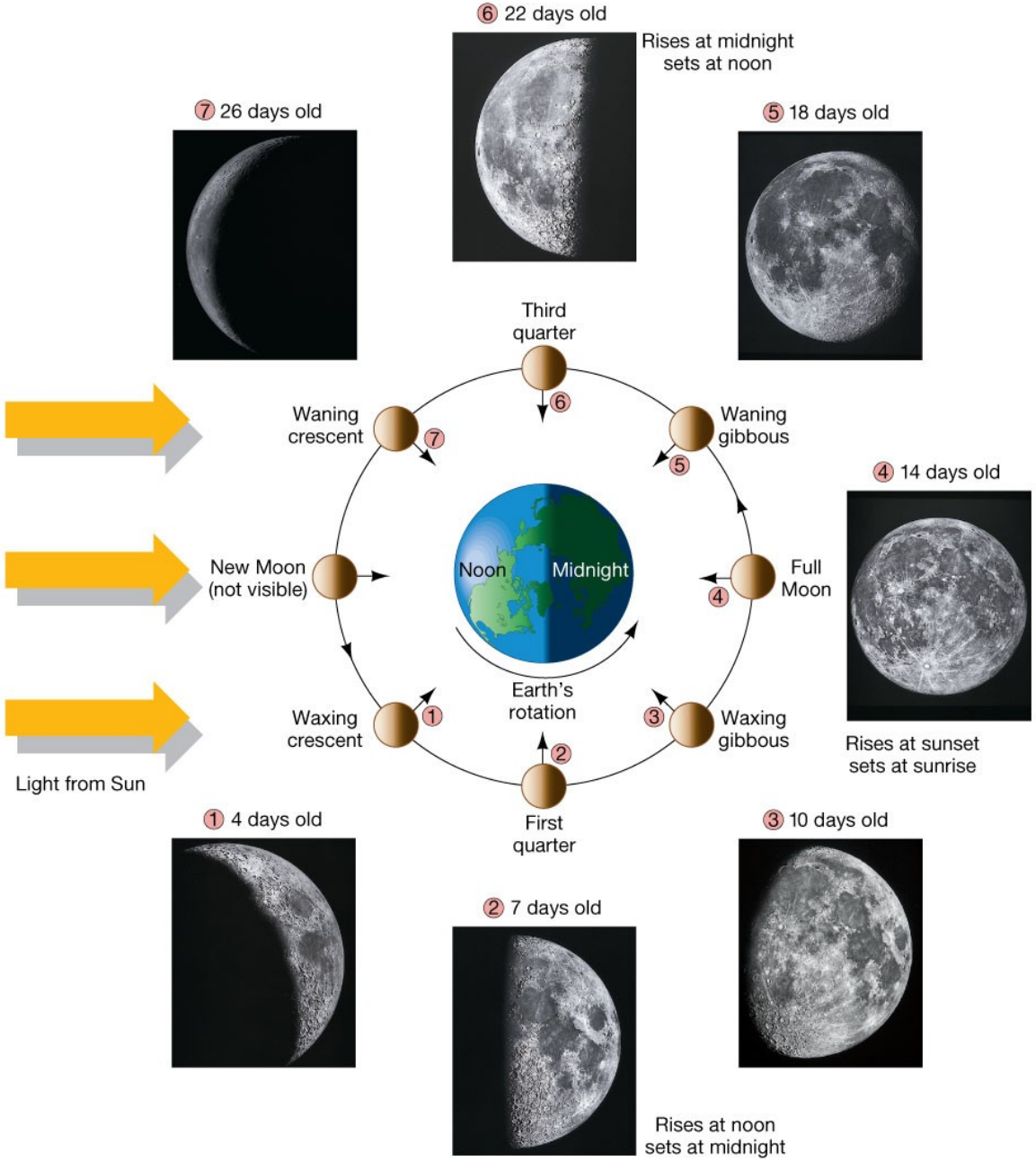
1.5 Motion of the Moon

Phases are due to different amounts of sunlit portion being visible from Earth.

Q: Seen from Earth, what angle (ccw) is between the Sun and the Full Moon?

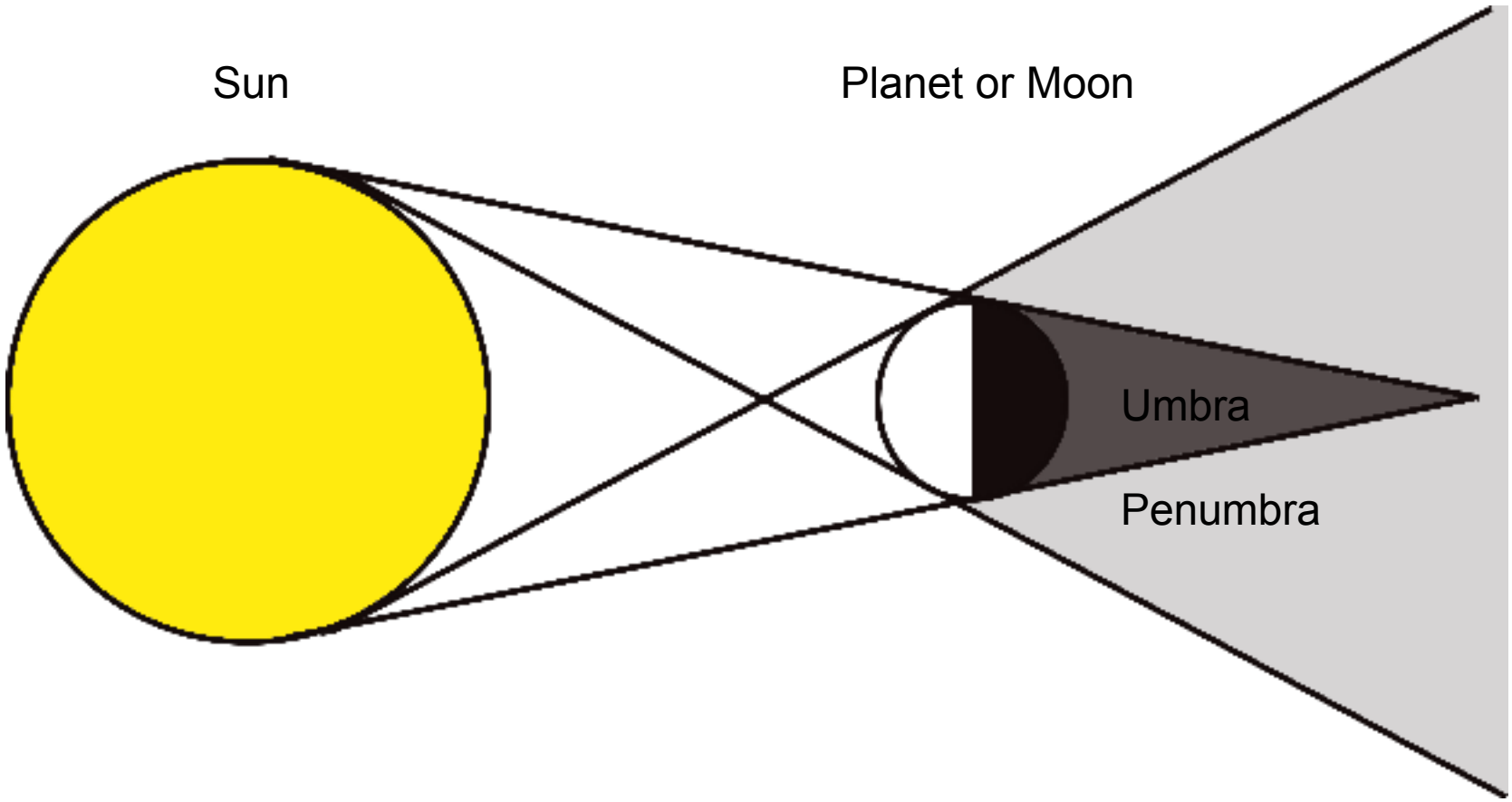
Q: Place a stick figure on Earth representing an observer experiencing morning.

Q: What time would a 1st quarter Moon rise?



© 2011 Pearson Education, Inc.

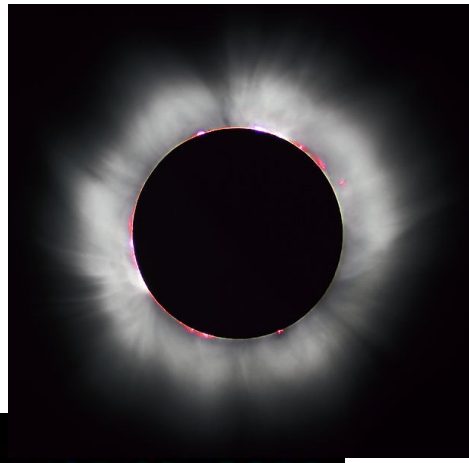
Eclipse Basics – the shadow cone geometry.



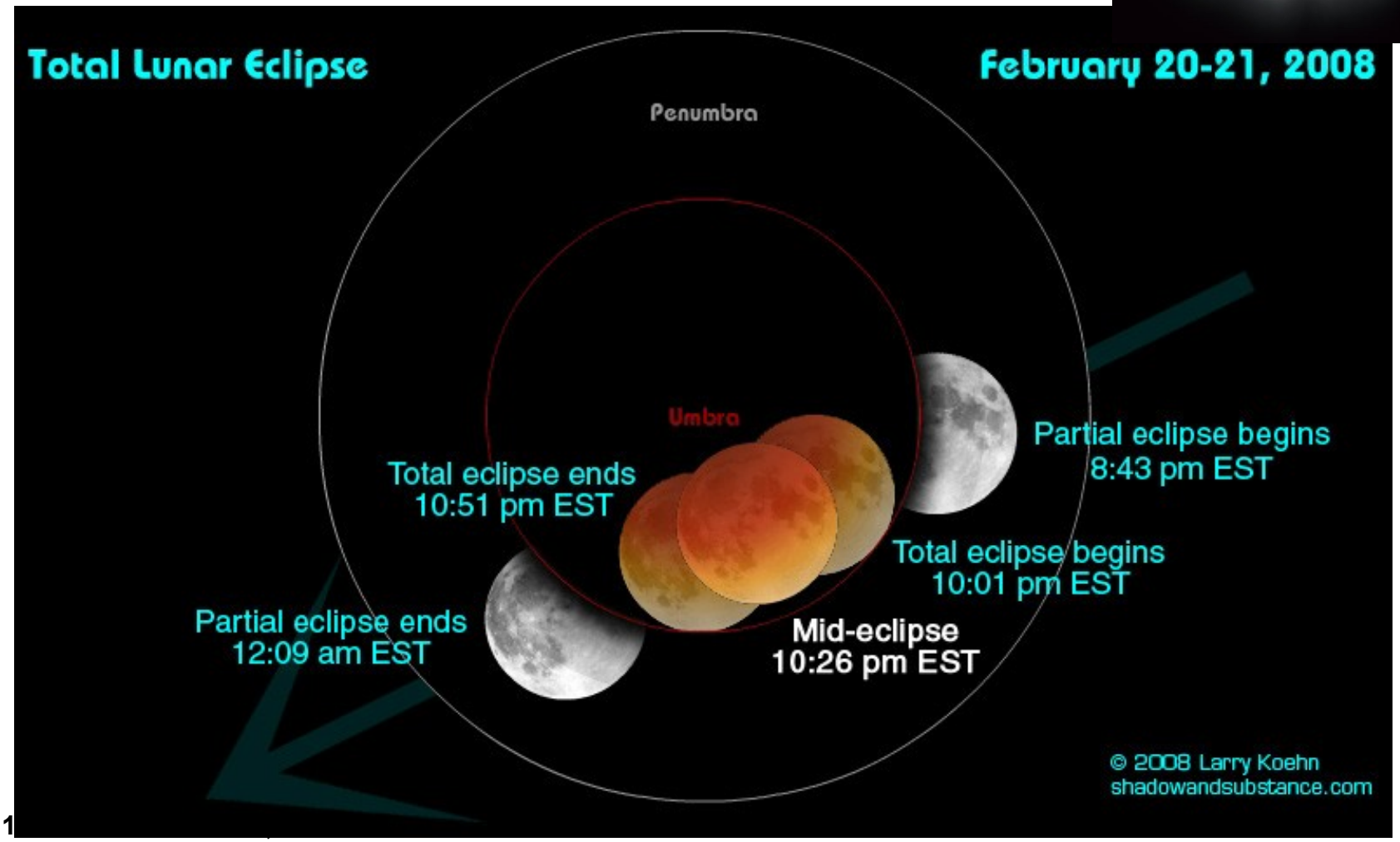
The Sun is actually about 110 times the Earth in diameter, and 400 times the Moon in diameter!

Eclipses – What are they?

A. Solar Eclipses: the Sun darkens



B. Lunar Eclipses: the Moon darkens



© 2011

Eclipse Basics.

Solar Eclipses – the shadow of the Moon falls on the Earth. We (on Earth) see the Sun get obscured.

TYPES: **Partial**
Annular
Hybrid or mixed **(e.g. start annular, end total)**
Total

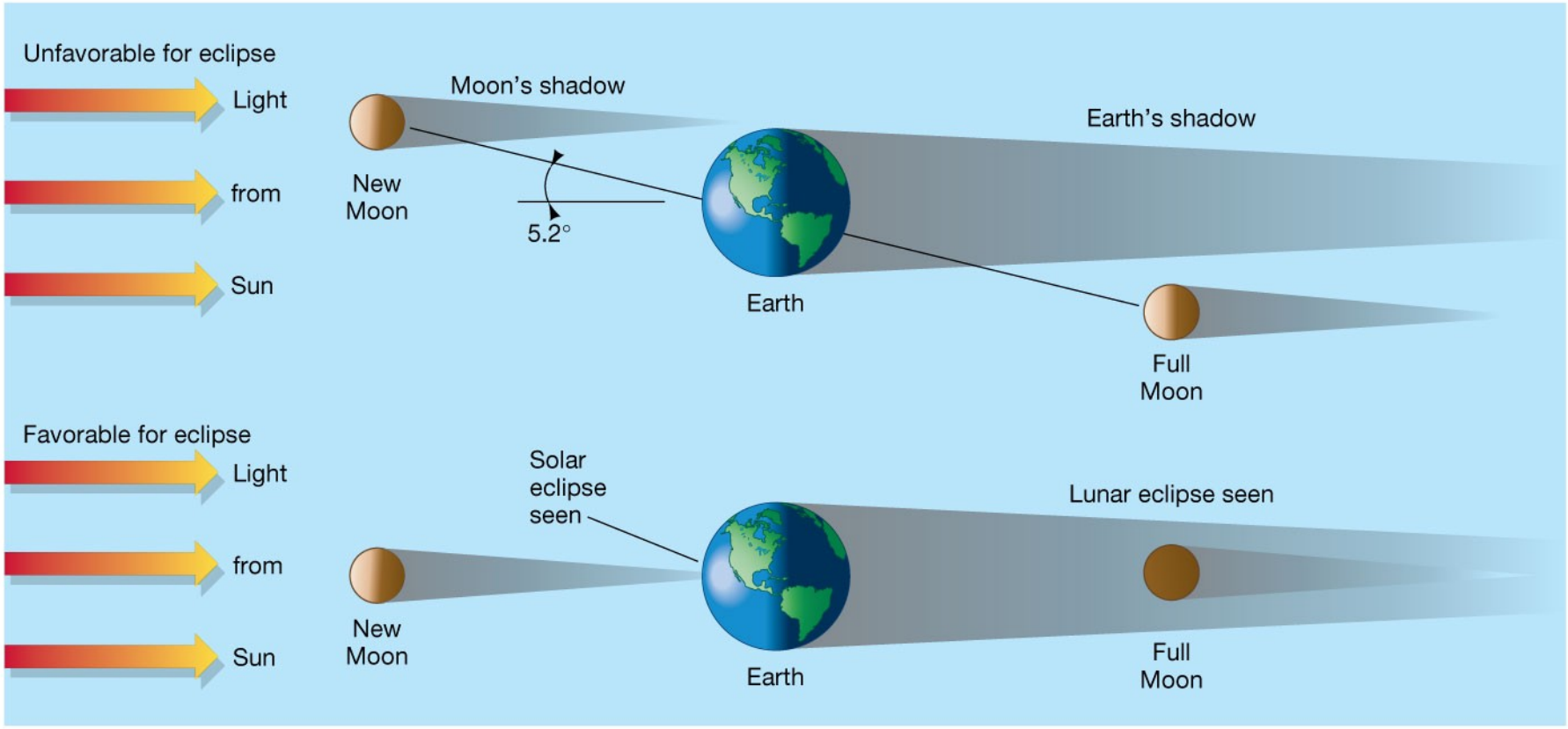
Lunar Eclipses – the shadow of the Earth falls on the Moon. We see a shadow pass over the Moon.

TYPES: **Penumbral**
Partial
Total

© 2011 Pearson Education, Inc.

1.5 Motion of the Moon – *Eclipses!*

Eclipses occur when Earth, Moon, and Sun form a straight line (*syzygy*).



(a)

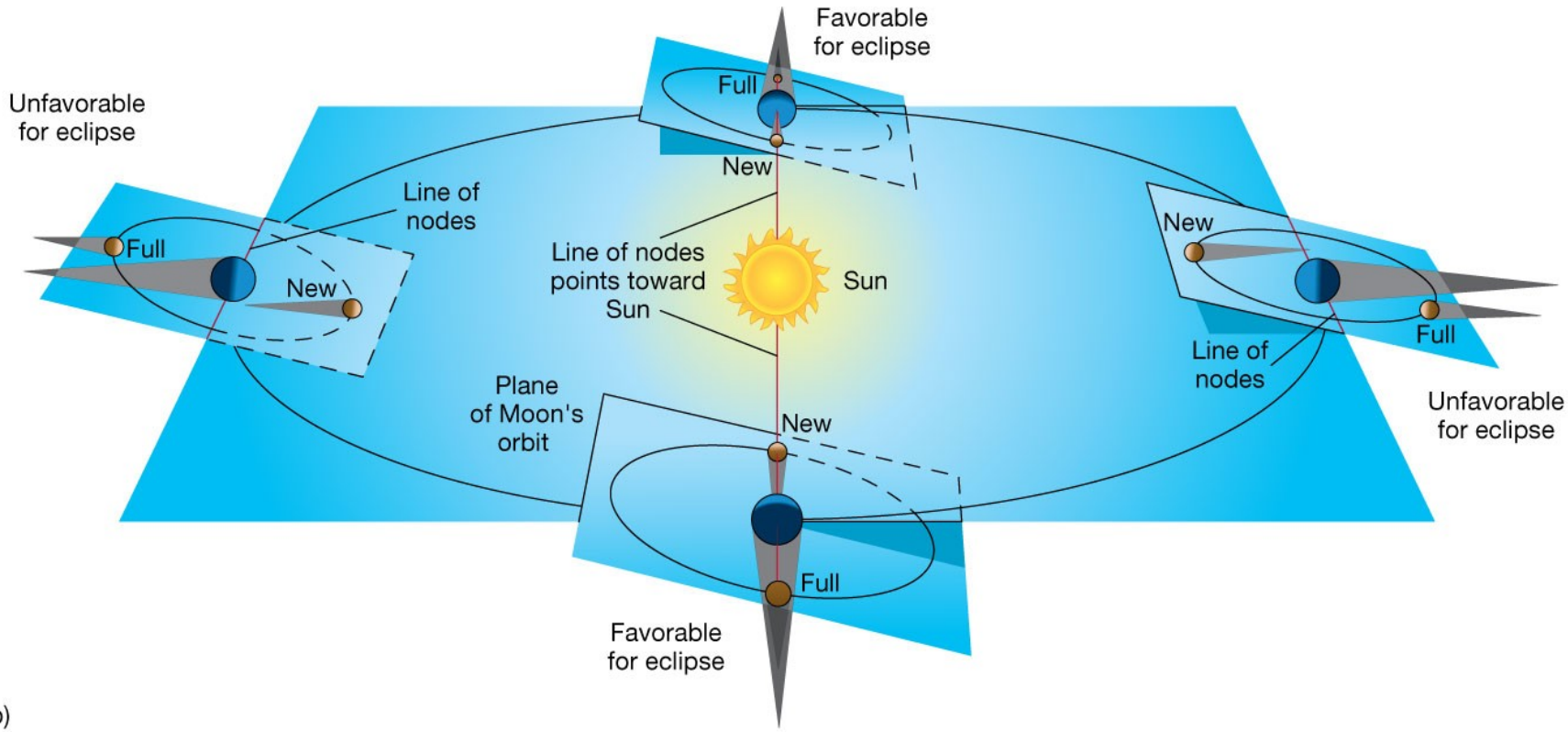
© 2011 Pearson Education, Inc.

Q: What phase does the Moon have to be in, if any, during a solar eclipse? During a lunar eclipse?

© 2011 Pearson Education, Inc.

1.5 Motion of the Moon

Eclipses don't occur every month because Earth's and Moon's orbits are not in the same plane

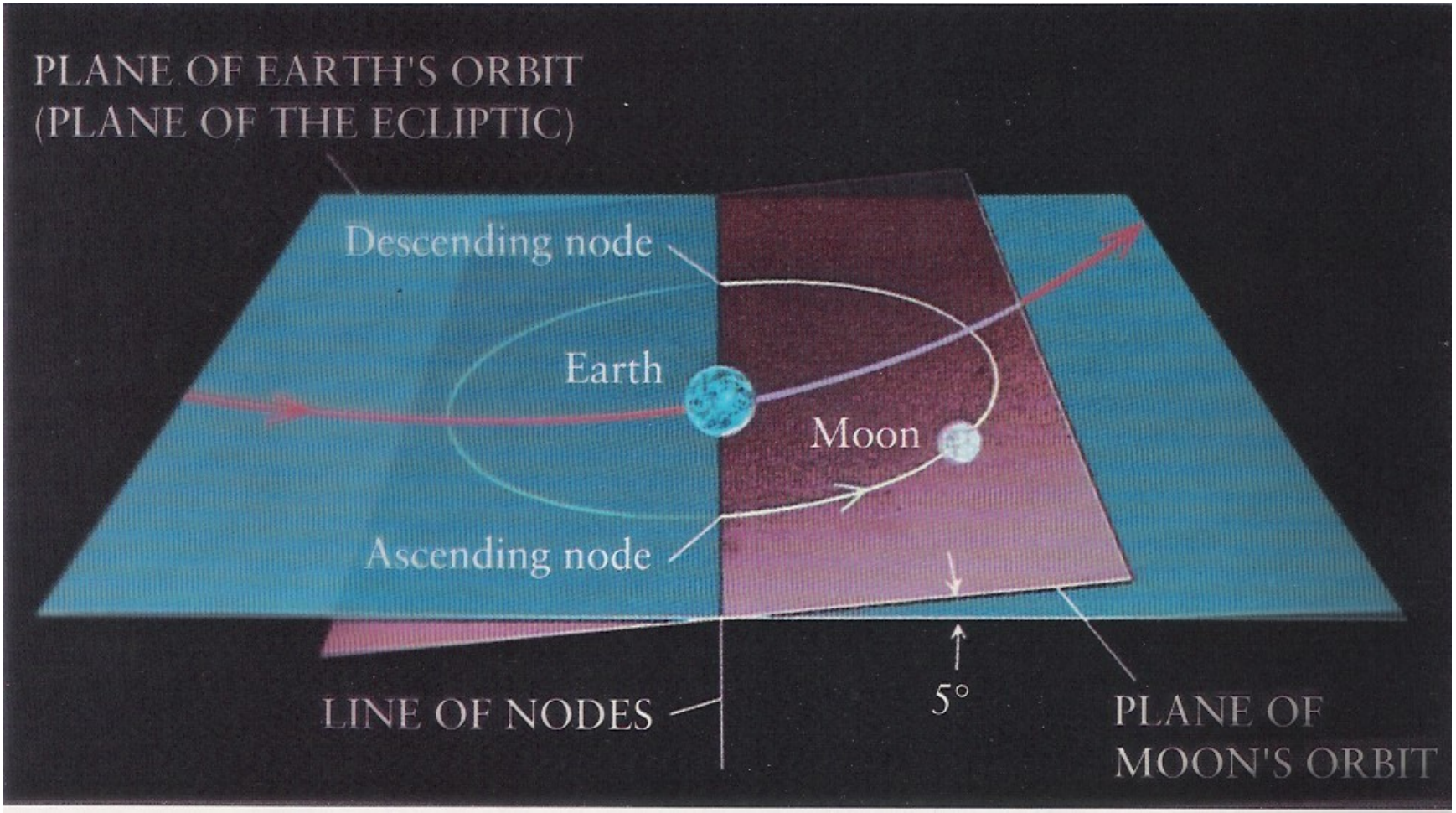


© 2011 Pearson Education, Inc.

1.5 Motion of the Moon

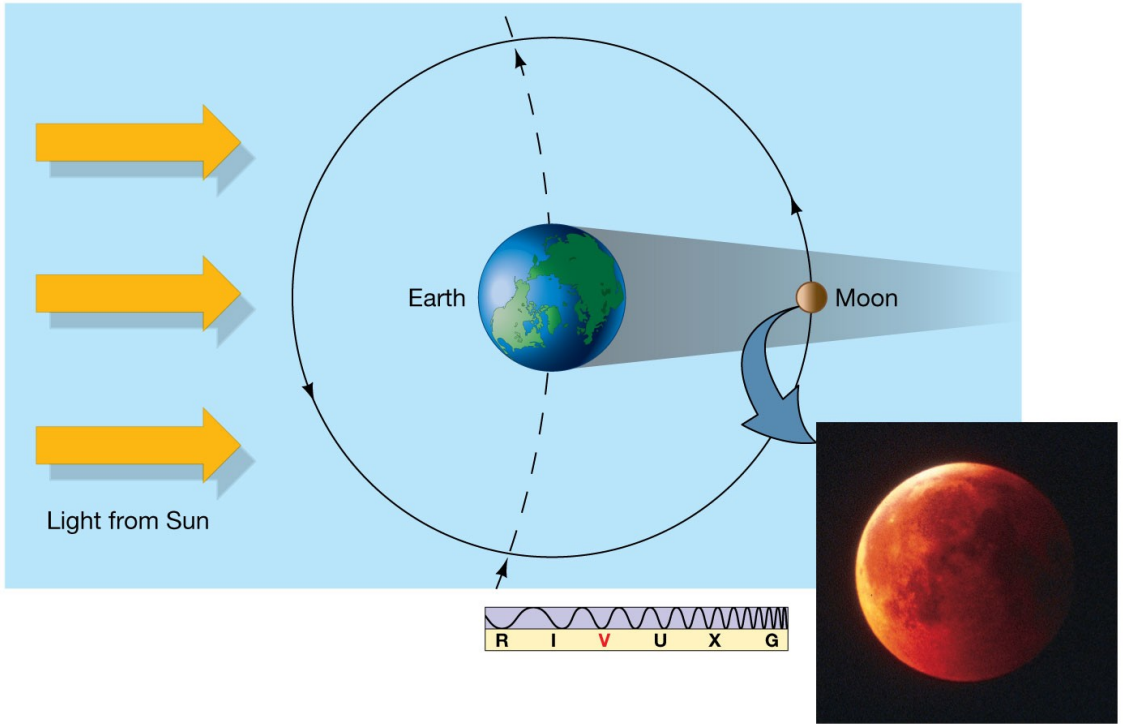
Moon's orbit intersects ecliptic plane at a *line of nodes*.

The line of nodes connects two points: an ascending node and a descending node.



Lunar eclipses – Earth is between Moon and Sun

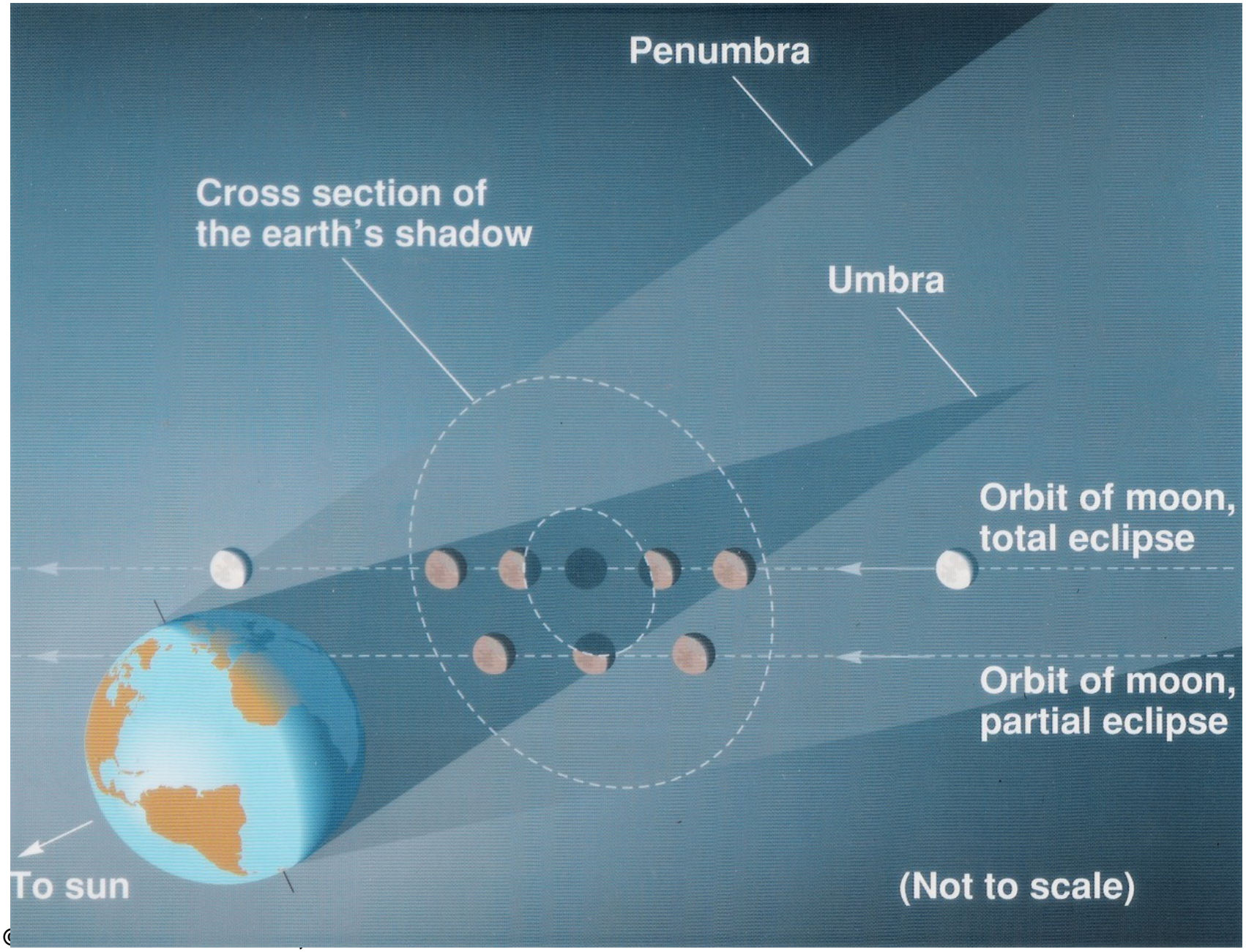
- Types determined by maximum immersion
- *Partial* if Moon only partially enters Umbra
- *Total* if Moon completely enters Umbra
- *Penumbral* when Moon only enters penumbra



© 2011 Pearson Education, Inc.

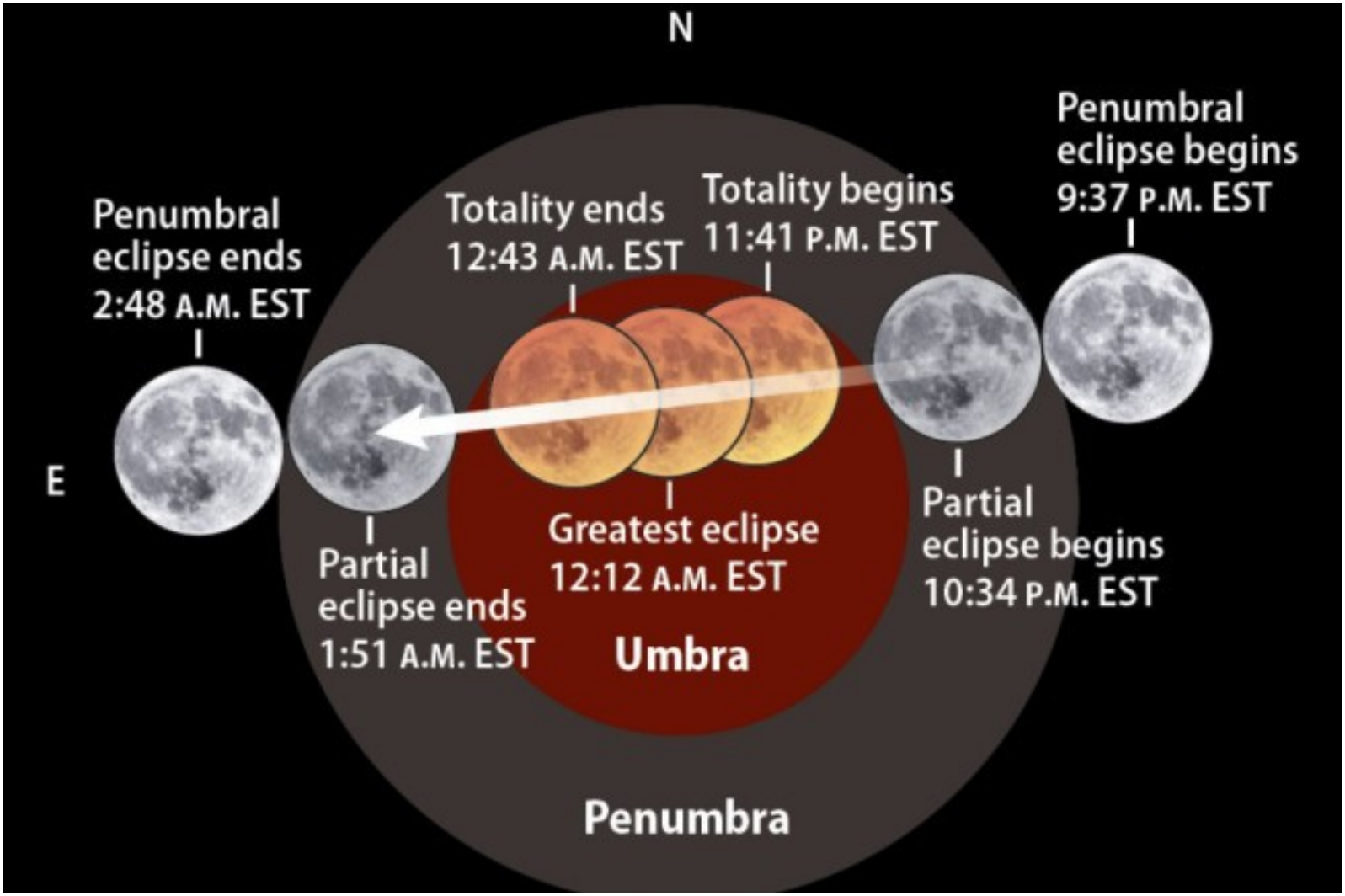
© 2011 Pearson Education, Inc.

Lunar eclipses – Earth is between Moon and Sun



Lunar Eclipses!

Total Lunar Eclipse, 1/20-21/2019



© 2011 Pearson Education, Inc.

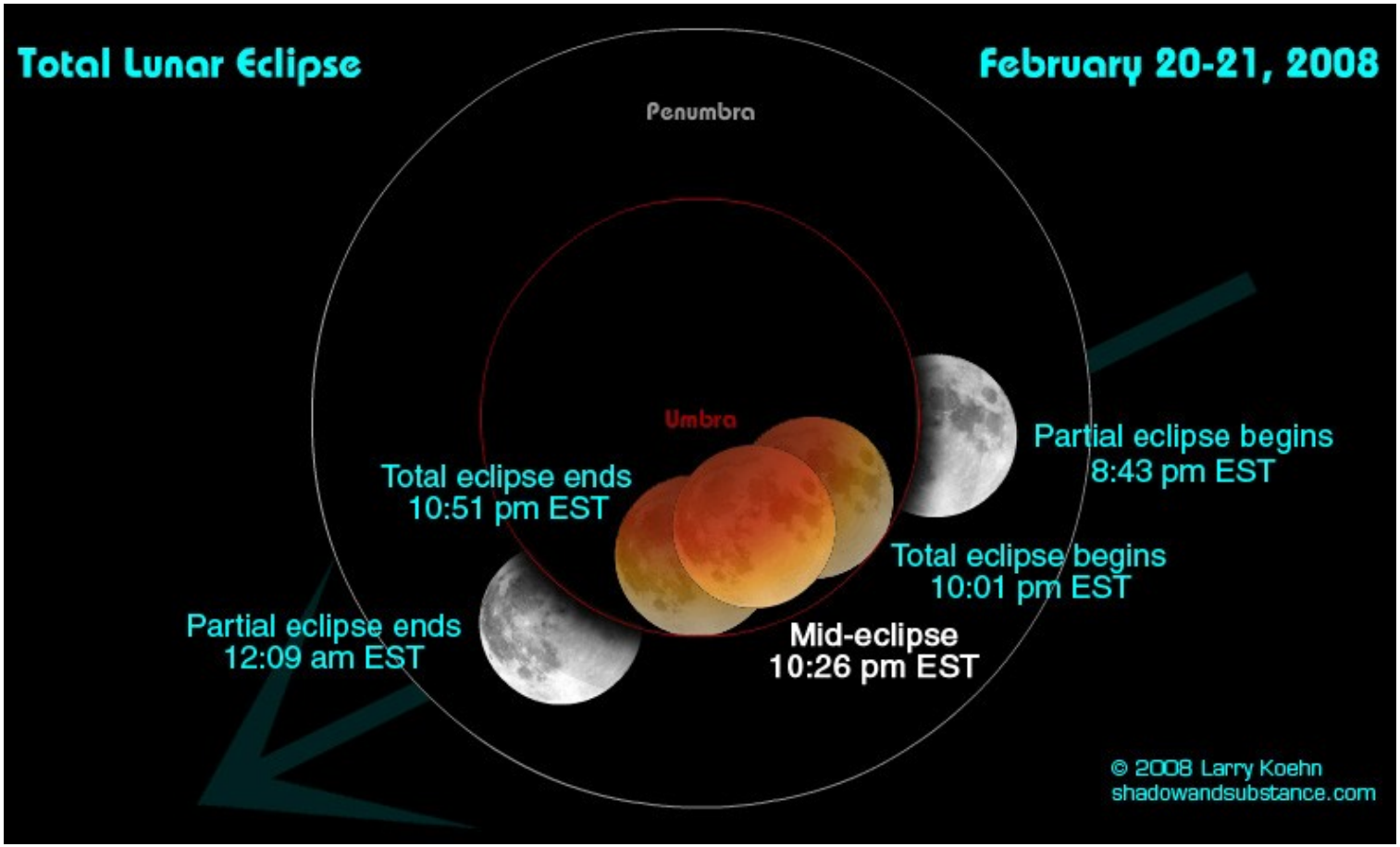
Lunar Eclipses!

My Pics from Jan 20-21, 2019 TLE

© 2011 Pearson Education, Inc.

Lunar Eclipses!

Total Lunar Eclipse, 2008

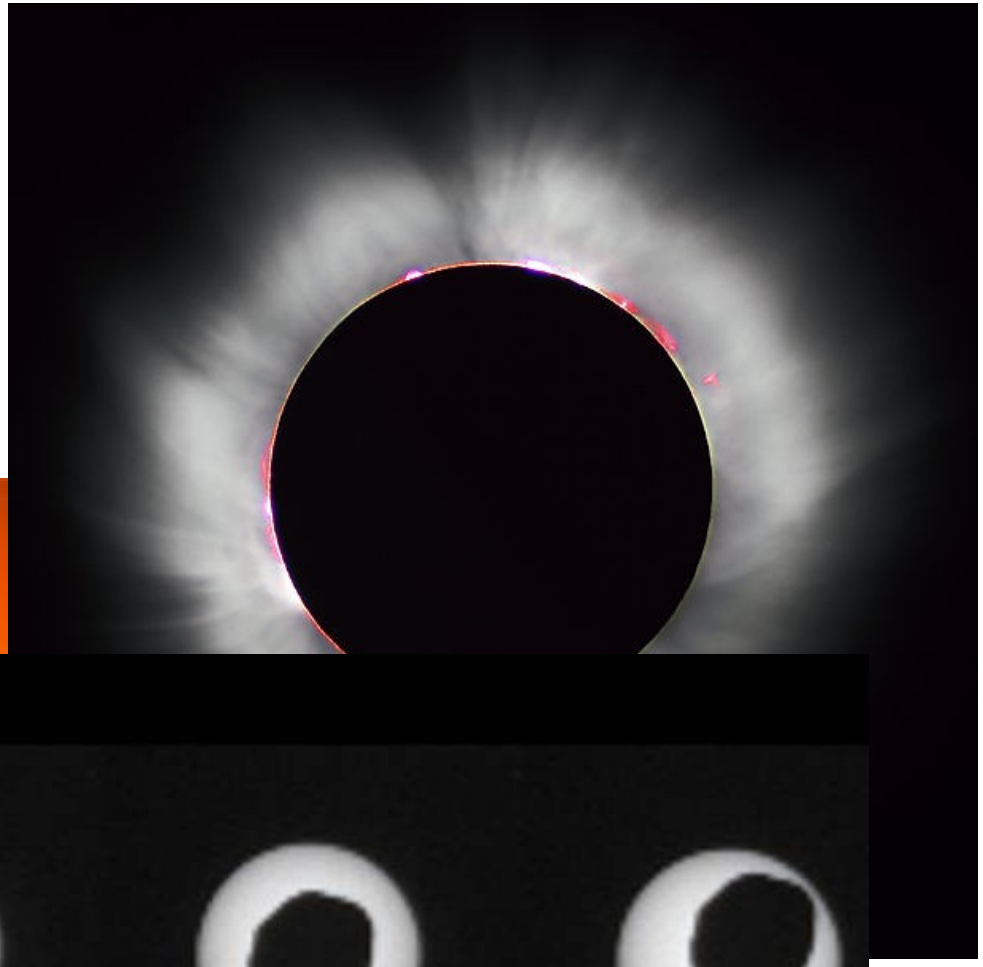


What's wrong with the labels?

© 2011 Pearson Education, Inc.

Solar Eclipses!

Total, 1999

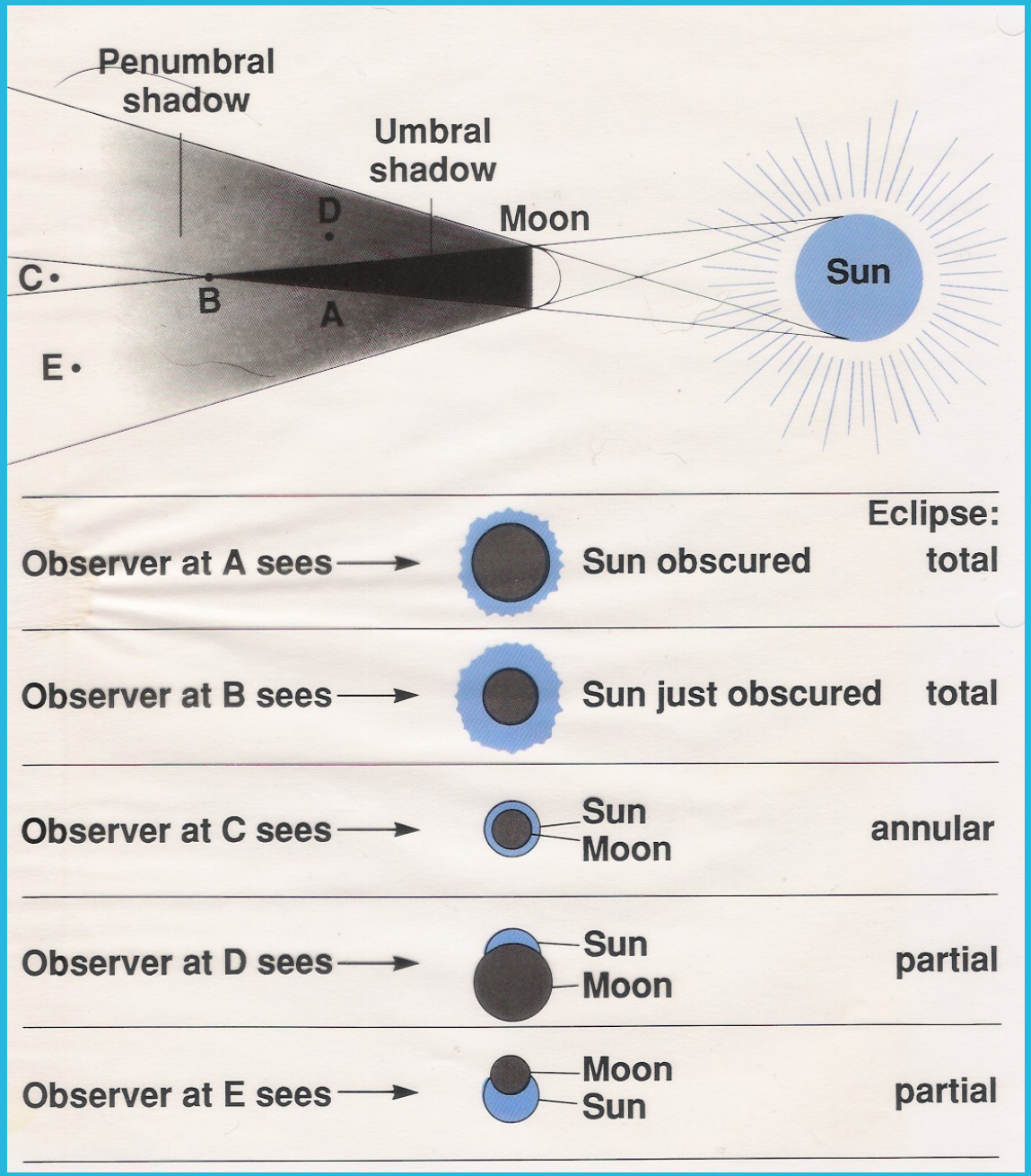


Annular 1994

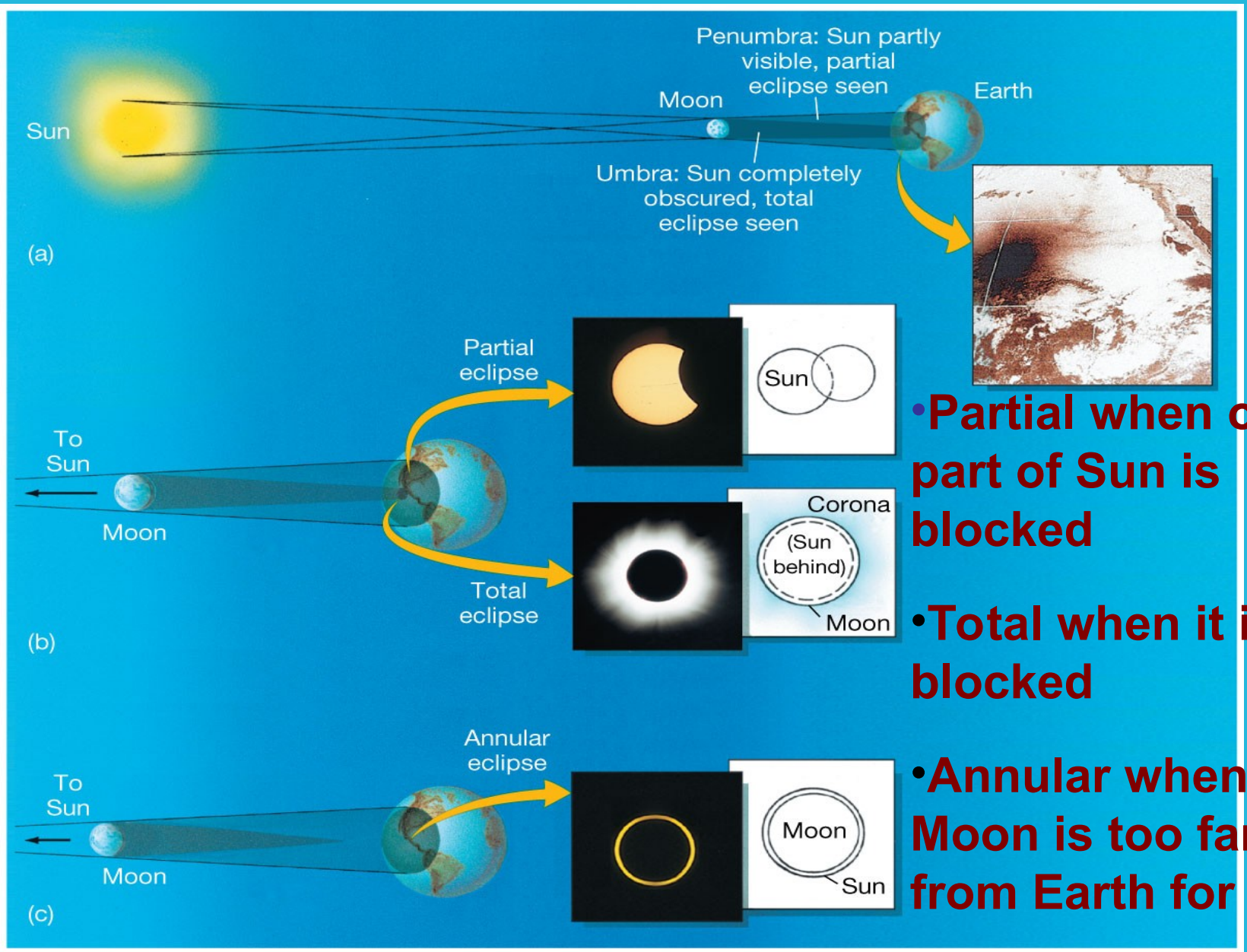
Phobos eclipses Sun, Aug 17, 2013

Solar eclipses - Moon is between Earth and Sun

A-E = possible positions of the Earth

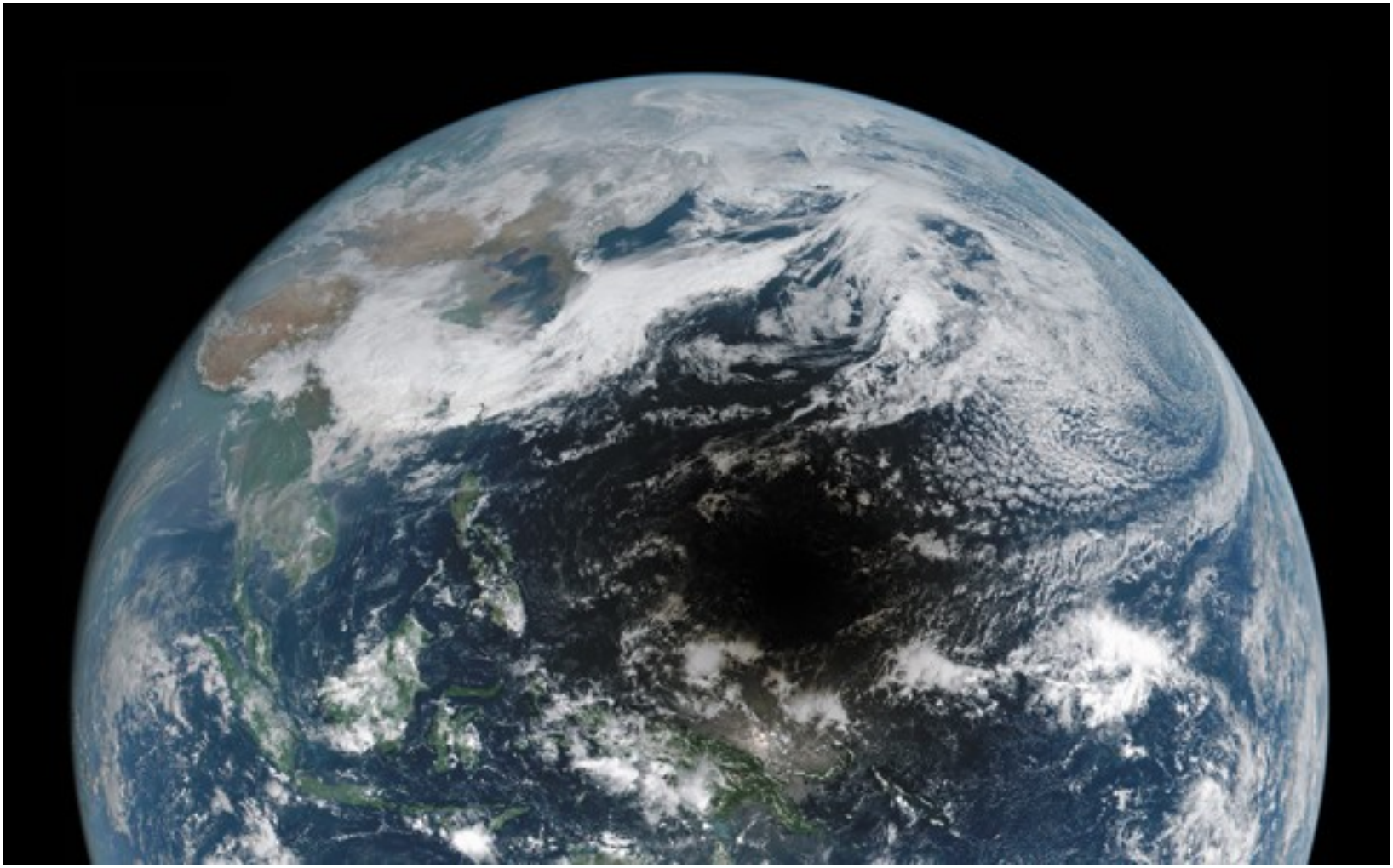


Solar eclipses - Moon is between Earth and Sun



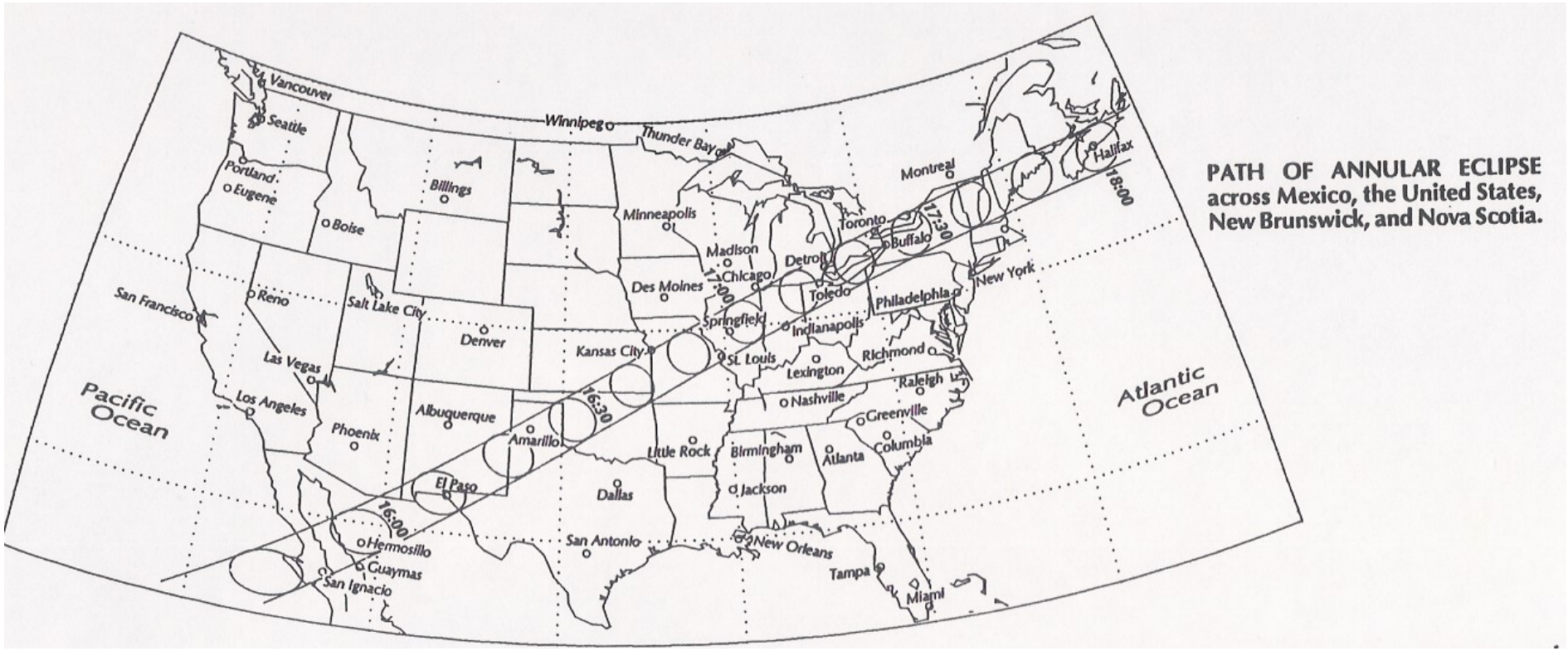
- Partial when only part of Sun is blocked
- Total when it is all blocked
- Annular when Moon is too far from Earth for total

© 2011 Pearson Education, Inc.



Satellite photo of Earth during Mar 9, 2016 total solar eclipse (total for Indonesia).

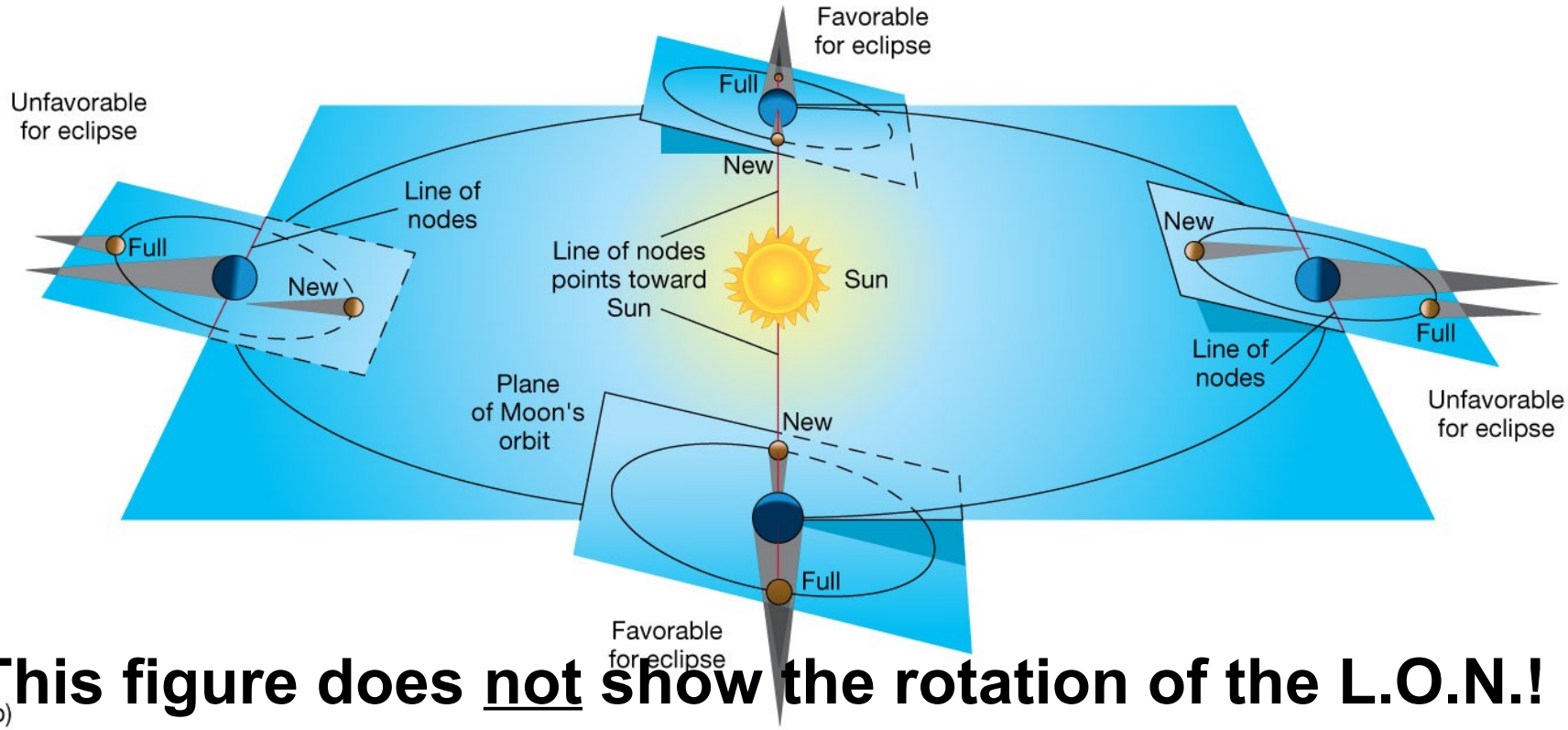
Solar Eclipse Paths



May, 1994

Predicting Eclipses

Lunar nodal precession period: 18.6 yrs for the L.O.N. to rotate CW. **Draconic year 346.6 days**



This figure does <u>not</u> show the rotation of the L.O.N.!

© 2011 Pearson Education, Inc.

Predicting Eclipses

Eclipses come in Seasons.
34.5 days in duration (on average, range 31-37 d)
5.7 calendar months apart
2x5.7=11.4 months is a Draconic year, the time it takes for the Sun to orbit relative to the line of nodes.

Other important periods for predicting eclipses are:
The synodic (phase) month (29.5 d)
The sidereal month (27.3 d)
The Draconic month (27.2 d) time to orbit relative to line of nodes).
The anomalistic month (27.55 d) time to orbit relative to the perigee.

Predicting Eclipses

Eclipse Seasons are about 5.7 months apart.

Eclipse Predictions by Fred Espenak, NASA's GSFC

Eclipse *frequencies*

There are a minimum of 4, and a maximum of 7 eclipses per year (all types included).

There is a minimum of 2, and a maximum of 5 solar eclipses per year. (Same for lunar.)

A lunar and solar eclipse are often 2 weeks apart.

(This is eclipsetable.swf.)

1.5 Predicting Eclipses

Eclipse *frequencies (cont.)*

Total solar eclipses occur *somewhere* on Earth about 2 times every 3 years (actually 0.60/year).

Total solar eclipses happen at a given location (like a small town) about once every 370 years, on average. Some spots will have to wait over 1000 years for their next total solar eclipse, while other lucky spots have two separated by 1.5 years.

Total lunar eclipses happen at a given location about once in 2 years because a TLE can be seen by half of the Earth at a given moment.

© 2011 Pearson Education, Inc.

Predicting Eclipses

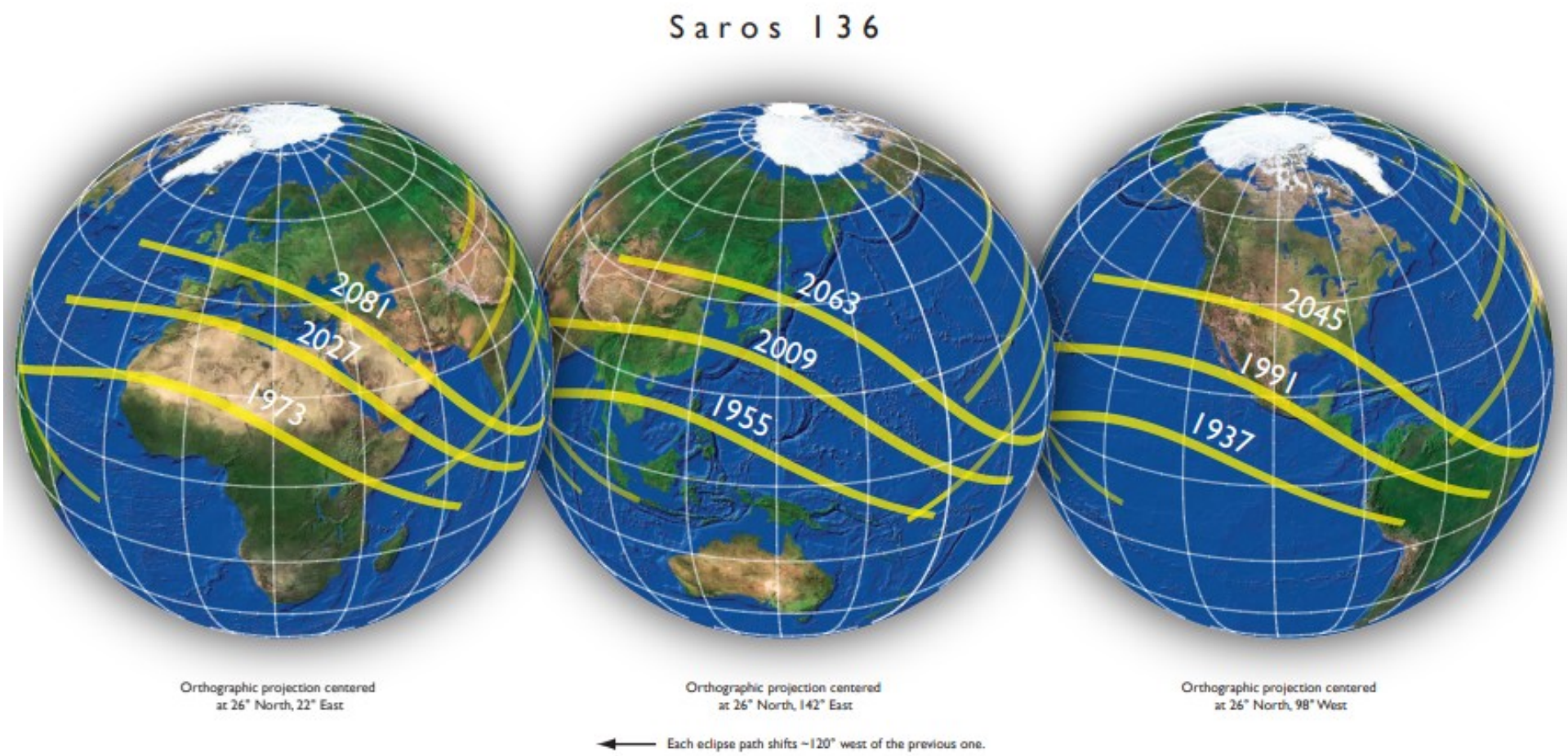
Every 18 yrs 11.33 days an eclipse of the same type will repeat on the same node (ascending or descending) and in the same part of the Moon's orbit (perigee, apogee, etc). This is a saros.

1 Saros = 6585.32 d (18 yrs 11 d 8 hrs)
~ 223 synodic months
~ 239 anomalistic months
~ 242 draconic months

Every 54 yrs 34 days, an eclipse will repeat as above but also on about the same place(s) on Earth.
This is an exeligmos.

© 2011 Pearson Education, Inc.

Predicting Eclipses

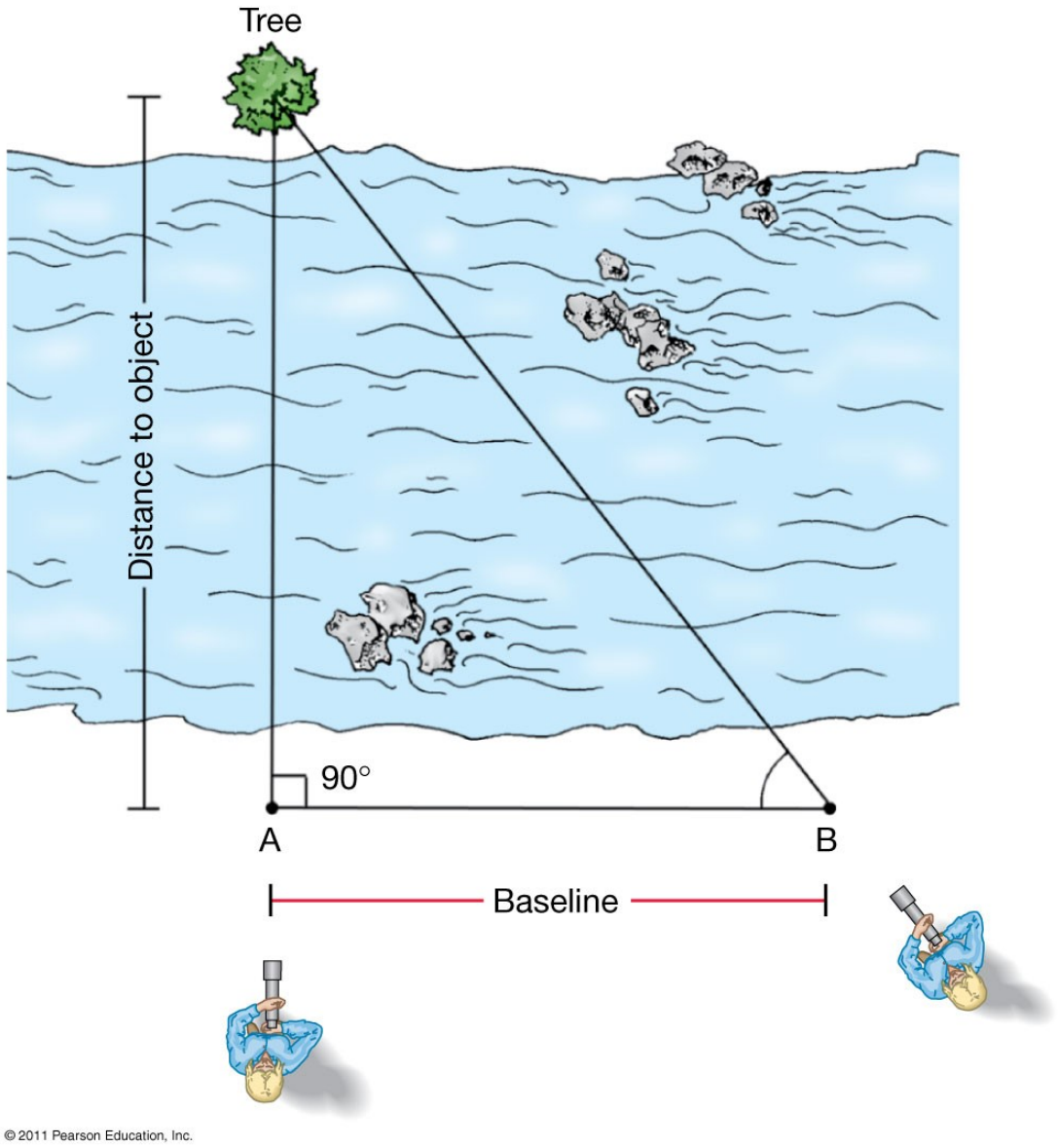


Saros series 136 will produce 71 eclipses over 1262 yrs (8part,6annul,6hyb, 44tot,7part)

© 2011 Pearson Education, Inc.

1.6 The Measurement of Distance

Triangulation:
Measure baseline and angles, can calculate distance



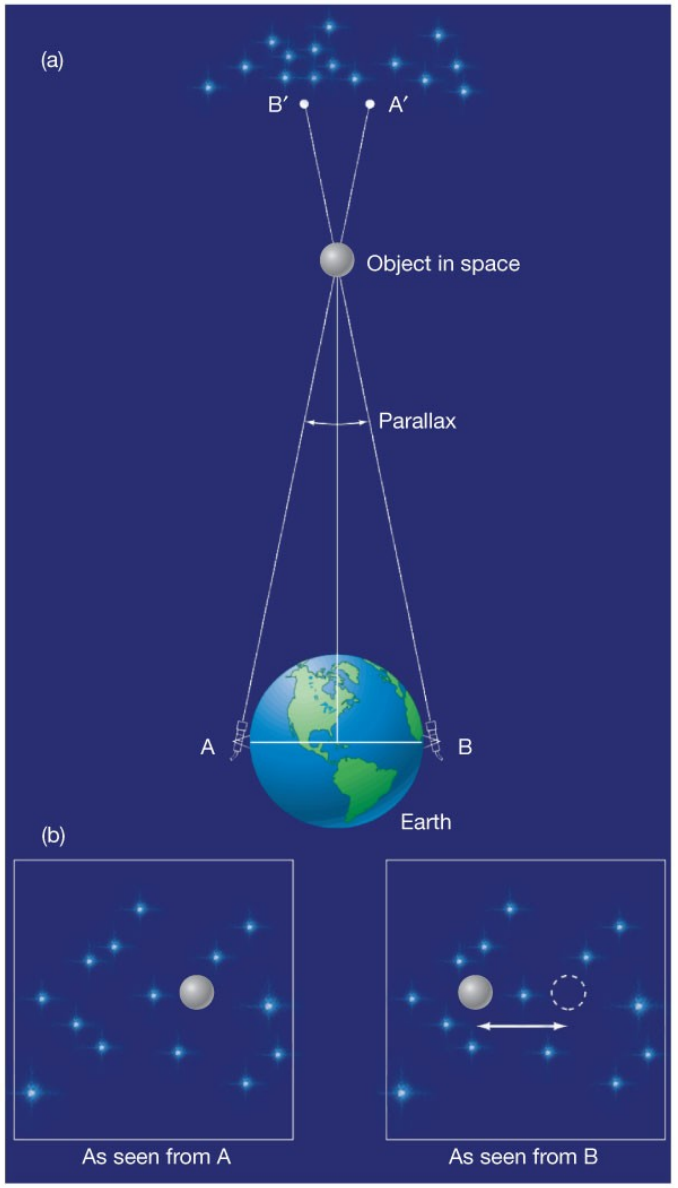
© 2011 Pearson Education, Inc.

© 2011 Pearson Education, Inc.

1.6 The Measurement of Distance

Parallax: Similar to triangulation, but look at apparent shift of object against distant background from two vantage points.

Change your POV to the object.
θ = LD/D becomes
parallax = Baseline/D



© 2011 Pearson Education, Inc.

© 2011 Pearson Education, Inc.

Summary of Chapter 1

- **Astronomy**: Study of the universe
- **Scientific method**: Observation, theory, prediction, observation, …
- We model the sky as a **celestial sphere** containing all of the stars as well as markings like the NCP and horizon
- Plane of Earth's orbit around Sun is **ecliptic**; tilted at 23.5° to celestial equator
- Tilt of Earth's axis causes **seasons**
- Moon shines by reflected light, has **phases**

© 2011 Pearson Education, Inc.

Summary of Chapter 1 (cont.)

- **Solar day > sidereal day**, due to Earth's revolution around Sun
- **Synodic month > sidereal month**, also due to Earth's revolution around Sun
- **Tropical year < sidereal year**, due to precession of Earth's spin axis
- **Eclipses of Sun and Moon** occur due to alignment; only occur occasionally as orbits are not in same plane
- Distances can be measured through **triangulation** and **parallax**

© 2011 Pearson Education, Inc.